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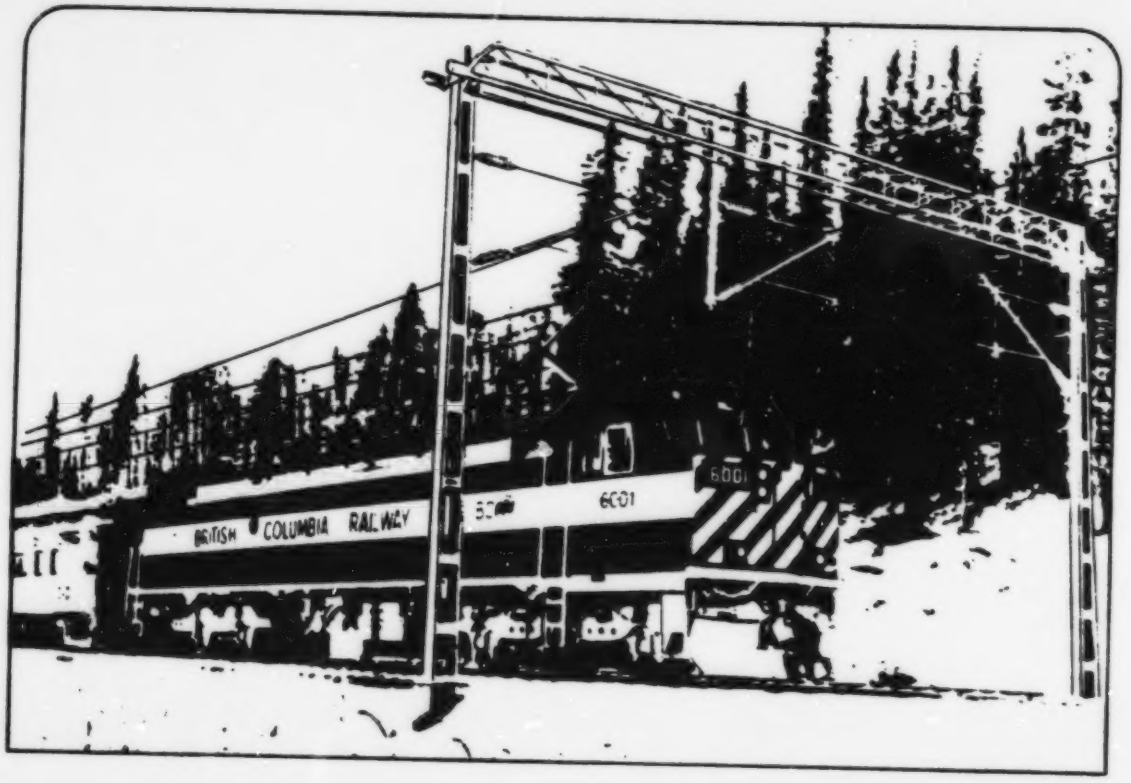

LOCATION, IDENTIFICATION, AND CONTROL (L.I.C.) SYSTEM IN AN ELECTRIFIED RAILWAY ENVIRONMENT

PREPARED FOR: TRANSPORTATION DEVELOPMENT CENTRE

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DECEMBER 1985

TP 7269E

EVALUATION OF THE LOCATION, IDENTIFICATION, AND CONTROL (L.I.C.) SYSTEM IN AN ELECTRIFIED RAILWAY ENVIRONMENT

by

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Un sommaire en francais de ce rapport est inclus avant la table des matieres.

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17. Abstract

This project describes BC Rail's continued development of a Canadian advanced train control system known as the "Location, Identification, and Control System" (L.I.C.S.). From 1979 to 1984, BC Rail developed, installed and tested L.I.C.S. on the Squamish Subdivision. Ultimately four major problems caused the project to be terminated. These were: (1) the host computer's front end processor was overloaded with tasks; (2) the system components with software were unable to operate for prolonged periods before their data bases became corrupted; (3) communication with trains too slow; and, (4) there were significant sections of track in which communication with trains was impossible.

This project reflects the practical engineering phase which followed the 1979-84 LIC system, and an attempt to correct the deficiencies identified. The reworked system was to be tested on the Squamish Subdivision and a portion of the electrified Tumbler Ridge Subdivision. During this practical engineering phase the system was extensively revised, but the original PDP 11/44 Host computers were retained. These computers could not support the reworked system and, as a result, the project was terminated without performing the field tests.

18 Key Words	19 Distribution Statement
Backbone Communications Network, Network Manager, On Board Train Processor, Remote Processing Unit, Wayside Communications Network, Wayside Processor.	Limited number of copies available from the Transportation Development Centre

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17. Résumé

Ce rapport concerne la mise au point par BC Rail du système LIC pour la localisation, l'identification et la commande de trains. De 1979 à 1984, BC Rail a posé et mis à l'essai ce système dans sa subdivision de Squamish. Mais il a fallu mettre un terme à la recherche devant les quatre grandes difficultés suivantes: 1) le processeur de données, organe de l'ordinateur central, était saturé; 2) le logiciel du processeur ne pouvait fonctionner longtemps sans introduire des erreurs dans la base de données; 3) la communication avec les trains était trop lente et 4) une bonne liaison hertzienne était difficile à établir avec d'importants tronçons de la voie.

Ce rapport rend compte des travaux techniques qui ont eu lieu après la mise en service expérimental du LIC de 1979 à 1984 et des tentatives pour remédier aux lacunes constatées. Le système remanié devait être testé dans la sudbivision de Squamish ainsi que sur un tronçon de la ligne électrifiée de Tumbler Ridge. Le système a subi d'importants changements sans qu'il y ait eu de modifications correspondantes dans le réseau d'ordinateurs principaux PDP 11/44 qui est resté le même. Ce réseau n'ayant pas les performances voulues, il en est résulté des défaillances qui ont entraîné la fin de la recherche avant que les tests prévus n'aient pu avoir lieu.

18 Mots-clés	19 Diffusion
Réseau principal de communication, gestion de réseau, processeur de données embarqué, unité de traitement télécommandée, réseau de communications fixes, processeur fixe.	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires

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SUMMARY

1. BACKGROUND

BC Rail has conducted a project entitled Evaluation of the Location, Identification and Control (LIC) System in an Electrified Railway Environment. The LIC system is a computer based train traffic management system. Computer equipment is used on board the locomotive, in the caboose, and at the dispatch office. The engineman is provided with a display unit which shows the operating authorities. Equipment installed in the caboose provides verification that the train has cleared a block. Train location, track usage and conditions relevant to train movements are displayed to the dispatcher via a colour video track diagram. Radio communications are employed to convey information between the train and the central dispatch office.

2. OBJECTIVES

The overall objectives of this phase were to:

i. Rewrite the Host computer software to encompass new Host design concepts.

ii. Redevelop the communications system to improve performance and correct the deficiencies of the old (1979-84) LIC system.

iii. Install the track inspection vehicle (V-10) with new LIC locomotive equipment to test the communications and tracking systems first in the Squamish subdivision and then in the Tumbler Ridge subdivision.

iv. Install a Remote Processing Unit (RPU) at a Tumbler Ridge microwave site.

v. Provide a dedicated voice grade microwave channel from the LIC equipped Tumbler Ridge site to the North Vancouver dispatching centre.

vi. Deploy track mounted transponders on a portion of the Tumbler Ridge branch line.

vii. Compare and evaluate the Tumbler Ridge test data against the Squamish test data.

3. COMMUNICATIONS DEVELOPMENT

The communications equipment has been redeveloped to increase performance. The 1979-84 Data Collection Processor has been separated into two components, a Network Manager and a Cluster Controller. This was done to achieve high efficiency.

Train communications are handled solely by the Network Manager. The Network Manager is the interface between the Host computer and the communications backbone. The Cluster Controller is a communications multiplexer that allows multiple messages to travel over the same line at once, thus the number of communications lines is drastically reduced. This reduces the cost of the equipment and improves maintenance aspects.

4. HOST COMPUTER SYSTEM

The Host computer software has been entirely rewritten to incorporate new design techniques. The development language has been changed to provide portability and flexibility. The computer operating system has been changed to obtain better software development tools.

The system software has been written to incorporate railway operations and not adhere to the rules of the railway as with 1979-84 LIC. The software has been written in a modular form to allow ease of program alteration and maintenance. This also allows interdependencies to be easily handled.

5. LOCOMOTIVE EQUIPMENT DEVELOPMENT AND INSTALLATION

The locomotive equipment was redeveloped to incorporate new design techniques. The 1979-84 LIC system comprised of an Engine Logic Unit and a Cab Display Unit. The Engine Logic Unit has been separated into two different parts, the Communications Processor and the On Board Train Processor. This was done to separate the communications function to achieve processing efficiency. The Cab Display Unit was upgraded to a Graphics Display Unit which incorporates graphical capabilities and an upgraded screen display.

The locomotive equipment was not installed on the track inspection vehicle (V-10) because the Host computer was not performing adequately.

6. TUMBLER RIDGE SUBDIVISION INSTALLATION AND TESTING

There were fifteen (15) transponders installed in an electrified railway environment. The Squamish subdivision had 65 transponders installed. The transponders that were installed in electrified territory were deployed with the same configuration as that in the Squamish subdivision between Miles 38 and 42; this is to allow for similar testing to be conducted. The RPU was not installed in the Tumbler Ridge subdivision; it was to be moved from the Squamish Subdivision after the completion of testing. The voice grade channel was provided between North Vancouver and electrified railway territory.

7. DEVELOPMENT PROBLEMS ENCOUNTERED

The Host computer and the operating system did not perform adequately. The problem was with inter-process communication and synchronization. The passing and sharing of data became the central issue in the Host computer design. Both hardware and software problems contributed to the Host problem.

8. CONCLUSIONS

The communications and train equipment have been redeveloped. The Host computer and operating system did not provide adequate performance and therefore testing of the electrified railway territory and Squamish subdivision could not commence on schedule. The transponders were installed in the electrified railway territory.

9. RECOMMENDATIONS

Based upon the experience gained during the project, the following recommendations are made:

i. Purchase an alternate Host computer and operating system.

ii. Extensively test communications system.

iii. Move software to new Host computer and commence testing in an electrified railway environment.

iv. A number of specific recommendations are made that pertain to system enhancements.

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1. SOMMAIRE

BC Rail a lancé un projet de recherche sur l'évaluation du système de localisation, d'identification et de commande de trains (LIC), appliqué à une ligne électrifiée, lequel système piloté par ordinateur sert à la régulation du trafic. Pour cela, des circuits logiques sont placés dans la cabine du train, dans le wagon de queue ainsi que dans le poste de contrôle. Les autorisations et ordres de manoeuvre sont affichés sur un écran placé dans la cabine de la locomotive. Le circuit placé dans le wagon de queue sert à indiquer le canton que le train vient de libérer. Tous les paramètres relatifs au train, a l'occupation d'un canton et aux conditions de marche sont affichés sous forme de graphique sur un écran couleur dans le poste de contrôle. L'information est transmise entre le train et ce poste de contrôle par des liaisons hertziennes.

2. OBJECTIFS

Les objectifs de la recherche ont été les suivants:

i. Remanier le programme afin qu'il mette à profit les progrès réalisés par le nouveau matériel informatique.

ii. Moderniser le réseau de transmission en vue de remédier aux lacunes de l'ancien système LIC (1979-1984) et pour améliorer les performances.

iii. Équiper l'engin d'auscultation des voies V-10 du nouveau système LIC dans le but de vérifier le système de communication et de repérage, d'abord dans la subdivision de Squamish et, ensuite, sur le tronçon électrifié de Tumbler Ridge.

iv. Équiper d'une unité de traitement télécommandée une des stations hertziennes de la subdivision de Tumbler Ridge.

v. Établir une liaison hertzienne de qualité téléphonique entre le tronçon de la ligne Tumbler Ridge équipé du système LIC et le centre de contrôle de North Vancouver.

vi. Installer des transpondeurs fixes le long du tronçon visé.

vii. Évaluer en les comparant les résultats obtenus de la subdivision de Squamish et du tronçon électrifié de Tumbler Ridge.

3. MATÉRIEL DE COMMUNICATION

Le matériel servant aux communications a été remanié et amelioré. Ainsi, l'ancien processeur de données est maintenant remplacé par deux organes distincts: un pour la gestion de l'information et un pour la gestion des faisceaux hertziens, aboutissant à une efficacité accrue dans la transmission et le traitement des messages.

Les communications du train sont réglées uniquement par l'organe de gestion de l'information, interface entre l'ordinateur principal et la liaison principale. L'organe de gestion des faisceaux hertziens est un multiplex permettant d'établir plusieurs communications au moyen d'une seule voie, ce qui réduit le nombre de voies à mettre en oeuvre, coupe les dépenses afférentes et facilite la maintenance.

4. MATÉRIEL INFORMATIQUE

Le programme a été complètement remanié de manière à pouvoir tirer profit des progrès realisés. Un langage de commande plus évolué a été adopté, apportant plus de mobilité et de souplesse au matériel. Même le système d'exploitation de l'ordinateur a été amélioré, facilitant la mise au point des logiciels.

Le nouveau programme a été rédigé en fonction des operations ferroviaires et non des règlements, comme cela était le cas avec l'ancien. De plus, il se présente sous forme modulaire, ce qui facilite les adaptations et la maintenance. Enfin, il rend plus facile la prise en compte des interdépendances.

5. MATÉRIEL DE BORD DE LOCOMOTVE

La locomotive a été modifiée afin d'y intégrer un matériel informatique modernisé. Auparavant, le matériel LIC embarqué était composé d'un processeur de données de la locomotive et d'un tableau d'affichage en cabine. Le processeur de données a été séparé en deux fonctions: transmission et traitement, de manière à optimaliser le traitement de l'information. Quant au tableau d'affichage, il comporte maintenant un matériel infographique plus moderne et un écran de performances supérieures.

L'engin d'auscultation de la voie V-10 n'a pas été équipé du système parce que l'ordinateur principal ne fonctionnait pas comme prévu.

6. INSTALLATION ET ESSAI DU SYSTÈME DANS LA SUBDIVISION TUMBLER RIDGE

Le tronçon électrifié a été equipé de 15 transpondeurs comparativement aux 65 de la subdivision de Squamish. On leur a donné la même configuration qu'entre les repères 38 et 42 de cette dernière, de façon à réaliser la similitude des conditions d'essai. Quant à la liaison hertzienne de qualité téléphonique, elle relie le tronçon électrifié au centre de contrôle de North Vancouver.

7. FAIBLESSES DU SYSTÈME

Ni l'ordinateur principal ni le système de surveillance des operations ferroviaires n'ont fonctionné comme prévu. Les difficultés rencontrées résidaient au niveau des communications entre processeurs et de leur synchronisation. Au niveau de l'ordinateur, les difficultés naissaient surtout dans la transmission et l'affectation des données. Enfin, tant le matériel que le logiciel ont contribué aux faiblesses attribuées a l'ordinateur principal.

8. CONCLUSIONS

Les matériels de communication et de bord ont été remainiés. Ni l'ordinateur principal ni le système de surveillance des opérations ferroviaires n'ont fonctionné comme prévu, de sorte que les essais n'ont pu commencer à temps, ni dans la subdivision de Squamish ni sur le tronçon électrifié qui a pourtant été équipé de tous les transpondeurs prévus.

9. RECOMMANDATIONS

Des résultats obtenus à ce jour, il est possible de formuler les recommandations suivantes:

i. Faire l'acquisition d'un ensemble ordinateur principal/système de surveillance plus puissant.

ii. Éprouver à fond le matériel de communication.

iii. Adapter le programme au nouvel ordinateur et en commencer l'essai sur le tronçon électrifié.

iv. Ameliorer le système dans son ensemble en adoptant les mesures préconisées.

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1. INTRODUCTION

The purpose of this document is to summarize the evaluation of the Location, Identification and Control (LIC) system in an electrified railway environment.

The LIC system is a computer based train traffic management system. Computer equipment is used on board the locomotive, in the caboose, and at the dispatch office. The engineman is provided with a display unit which shows the operating authorities. Equipment installed in the caboose provides verification that the train has cleared a block. Train location, track usage and conditions relevant to train movements are displayed to the dispatcher via a colour video track diagram.

Radio communications are employed to convey information between the train and the central dispatch office. The engineman's information is updated automatically but he must acknowledge certain directives. The acknowledge procedure is also used to convey agreement with changes in operating authorities which are required by the dispatcher.

1.1 Objectives of LIC in an Electrified Railway Environment

The following is a list of the objectives for this LIC project:

- rewrite the Host computer software to encompass new Host design concepts.
- redevelop the communications system to improve performance and correct the deficiencies of the 1979-84 LIC system.
- install the track inspection vehicle (V-10) with new LIC locomotive equipment to test the communications and tracking systems first in the Squamish subdivision and then in the Tumbler Ridge subdivision.
- provide a dedicated voice grade microwave channel from the LIC equipped Tumbler Ridge site to the North Vancouver dispatching centre.
- install a Remote Processing Unit (RPU) at a Tumbler Ridge microwave site.
- deploy track mounted transponders on a portion of the Tumbler Ridge branch line.
- compare and evaluate the Tumbler Ridge test data against the Squamish test data.

2. COMMUNICATIONS DEVELOPMENT

2.1 System Comparison

The train communications link is as shown in Figure 2-1. The Network Manager is the interface between the Host computer and the communications backbone. The Network Manager is separate from the Host computer to allow the Host computer to specialize in the data processing function and not be involved with any communications. The host passes the Network Manager the message with its destination and from there the Network Manager takes over.

A Cluster Controller is a communications multiplexer, allowing more than one signal to travel over one communication line, therefore the number of communications lines have been reduced. This reduces the cost of equipment and improves maintenance aspects.

The Network Manager has eight data communication channels. Each one of these data channels is capable of holding eight Cluster Controllers. Each Cluster Controller is connected to four remote radio sites. The site processors reside in the site repeater and communicate directly to the radio equipped units. The above configuration allows for a total of 256 different remote radio sites as opposed to the 6 that the 1979-84 system allowed.

Train communications are handled by the Network Manager. When a train reaches a cell overlap area (see Figure 2-2), the Network Manager automatically reroutes communications from the old cell to the new one. All cell overlap areas are stored in a table. The table holds the following items:

- track mileage
- cell to use
- signal strength signal quality
- average percentage of success rate

The table is referred to constantly and when the train reaches an overlap area the Network Manager executes the switch mentioned above.

The present LIC communications system is configured with an RPU replacing the Remote Site Unit (which is basically a modem) from LIC. This configuration is a contention system. This system allows for multiple frequencies and full duplex communications. Full duplex communications allows communications in two directions at the same time. The data rate of communications has been changed from 300 to 1200 b.p.s. and upward to increase the throughput of the system.

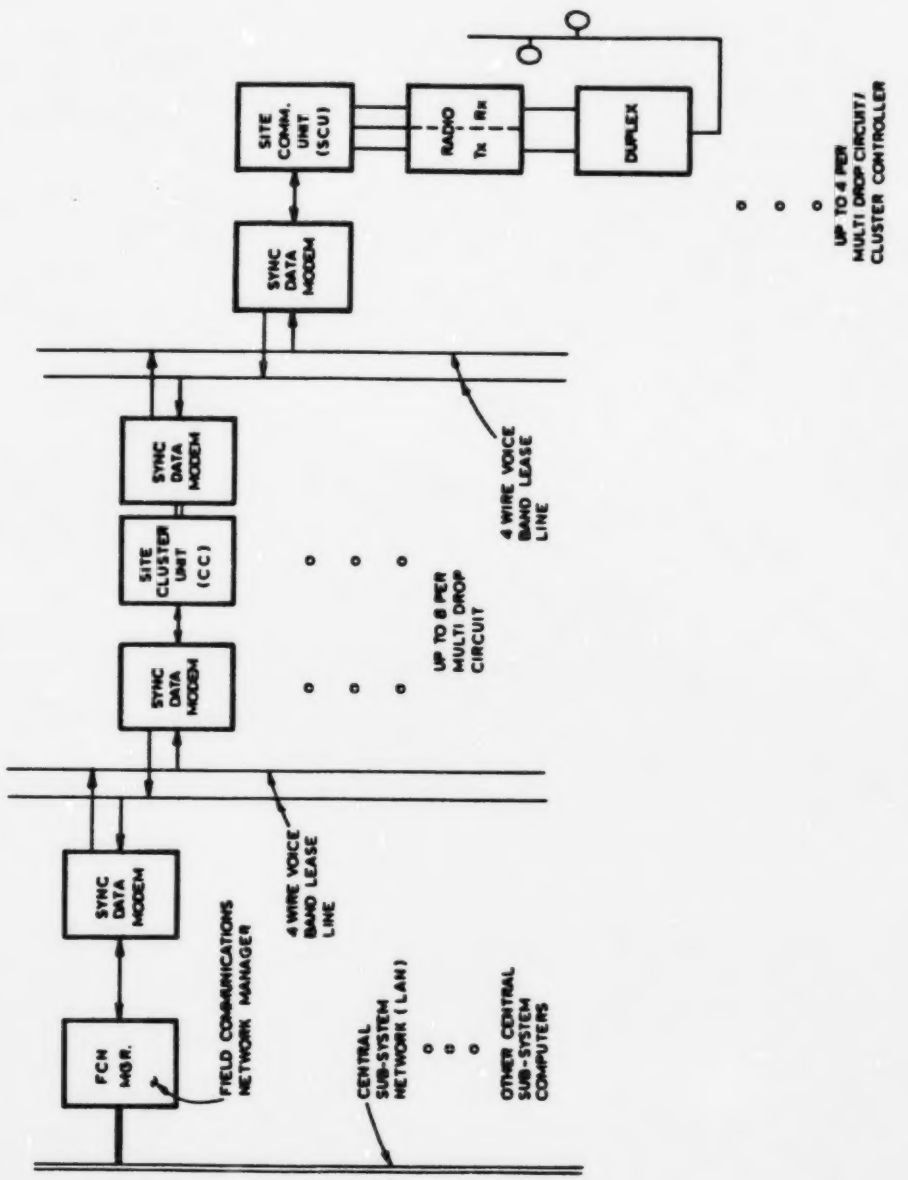
SITE COMM. UNIT (SCU)
RADIO
Tx | Rx
DUPLEX
UP TO 4 PER MULTI DROP CIRCUIT/ CLUSTER CONTROLLER
SYNC DATA MODEM
4 WIRE VOICE BAND LEASE LINE
SITE CLUSTER UNIT (CC)
UP TO 8 PER MULTI DROP CIRCUIT
FCN MGR.
FIELD COMMUNICATIONS NETWORK MANAGER
CENTRAL SUB-SYSTEM NETWORK (LAN)
OTHER CENTRAL SUB-SYSTEM COMPUTERS

Figure 2-1 LIC Communications Block Diagram

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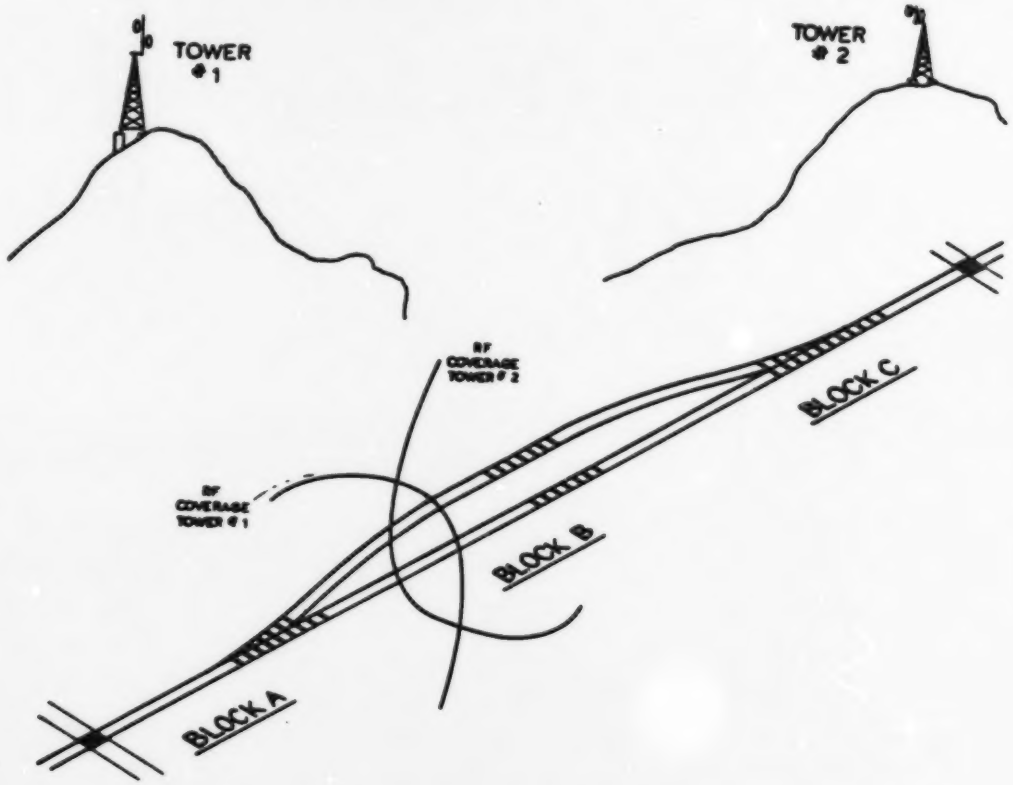

Figure 2-2 LIC Communications Two Cell Interference

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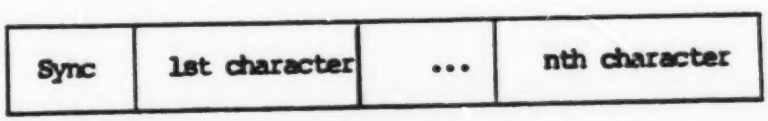
The 1979-84 LIC system consisted of a Data Collection Processor (DCP), Remote Site Unit (RSU), and a site radio. This configuration was a polled system. The 1979-84 LIC system only allowed for one frequency and a half duplex communication. Half duplex communications allows communications in two directions but not at the same time, the messages must alternate. The 1979-84 LIC system only had a 300 b.p.s. rate of communications and used asynchronous transmission. There was no error correction built into this system.

The 1979-84 LIC Data Collection Processor (DCP) has been replaced by the Network Manager and Cluster Controller. The DCP functions have been separated into two components to achieve higher efficiency in the communications system. Also, the tracking and conflict checking have been incorporated into the Host computer instead of the DCP. This leaves the Network Manager to deal solely with the communications function and not be burdened with other processing.

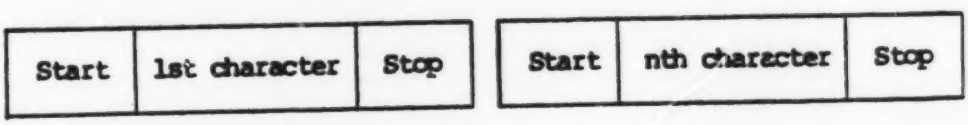
Synchronous transmission has been choeen over asynchronous because of the following reasons:

- more efficient bit-wise
- better burst error rejection

Synchronous transmission uses a sync character or characters for each entire message but asynchronous uses a series of start bits and stop bits for each character sent (see Figure 2-3).



Synchronous Transmission



Asynchronous Transmission

Figure 2-3

2.2 Network Manager

The Network Manager performs the following tasks:

- communicates to the Host computer via a data link.
- determines the route for incoming messages and retransmits the message to the appropriate Cluster Controller/Host with 100% reliability.
- changes fixed and mobile message routing as new routes are added and previous ones change (mobile moves to new Cluster Controller's coverage and a new mobile login).
- initiates a 'Mobile Unit Seek' function in system units to establish a virtual connection with a mobile unit; this occurs each time a unit is put into service.
- coordinates error recovery for all lower Backbone Communications Network (BCN) sub-systems. (The BCN is a communications link between the central site and each train in the system).
- coordinates diagnostic functions (such as signal quality and strength sampling at remote site processors).
- maintains a master copy of the track profile from which a desired portion is transmitted to the site processors as required via the Backbone Communications Network.
- maintains a master library of all software for all Backbone Communications Network sub-systems.

2.3 Cluster Controller

The Cluster Controller performs the following functions:

- communicates via a serial channel and modem to the Backbone Communications Network sub-system.
- maintains an overlaid RF (communications) profile and a track profile of all site processors in the Cluster Controller's control sphere.
- determines when a mobile unit must change its communications to another site (cell).
- changes site (cell) routing lists to reflect mobile units crossing site coverage boundaries.
- buffers messages to/from all networks attached to the Cluster Controller.

2.4 Site Processor

The Site Processor performs the following functions:

- communicates to the Cluster Controllers via the Backbone Communications Network.
- communicates to mobile units in the cell via a preselected frequency based on cluster communications.

- determines if a specific unit resides within radio coverage limits.
- maintains a cellular contention type network that contains a number of mobile units.
- maintains trunk accesses.
- determines when communication errors exist, if so, gathers statistics, and reports to the Cluster Controller (after retry, message rebuild procedures fail to be effective thus a cell failure occurs).
- prioritizes messages to/from mobile units to ensure appropriate response times are given to high priority messages (for example, emergency messages).
- performs constant background diagnostics on all appropriate components to ensure reliable operation.

2.5 Communications Processor

The Communications Processor performs the following duties:

- calculates/checks CRC.
- performs the first four layers of the International Standards Organization (ISO) Open System Interface (OSI).
- error detection.
- error correction.
- polling when required.
- radio control (frequency and power).

The Communications Processor has introduced some intelligence into the system by incorporating the above mentioned items. This reduces the development and maintenance costs by being a universal module (On Board Train Processor (OBT), Site, Wayside Communications Network (WCN), Wayside Processor (WSP)).

2.6 Modem

A 1200 b.p.s. FFSK (MSK) modem has been developed and tested. This modem was selected because of its ability to deal with burst noise and other such phenomenon that are found in the mobile environment. Also, this technology was readily available and did not have any proprietary nature for which availability could become a problem.

2.7 Message Format

The message format has been changed from the Glenayre message format to the EEA message format (see Appendix A). The EEA message format is 96 bits long as opposed to the Glenayre message format which is 390 bits long; therefore the packet is shorter which allows for better burst error rejection due to Rayleigh fading and multipath in a moving target.

3. HOST COMPUTER SYSTEM

3.1 System Comparison

In order to minimize cost the Host computer hardware has remained the same for the 1979-84 LIC project (contract #OST78-00217) as well as the present project (contract #OSB83-00323), a DEC PDP-11/44 and various peripherals are being used. The development language was changed from Fortran to 'C' for the following reasons:

- portability.
- flexibility.
- it allows high level structures and data types while also allowing for low level bit-wise operations.
- better modularity and structure control.

The operating system has been changed from RSX-11 to Ultrix-11 for the following reasons:

- much better support for 'C' under Ultrix-11.
- the cost for obtaining 'C' compiler for RSX-11 was too high.
- better software development tools.

The Host computer software has been entirely rewritten in 'C' under the new operating system. The present software has not been written with the same concepts as 1979-84 LIC. The 1979-84 LIC system was designed and written to adhere to the rules of the railway. The present system was designed to incorporate the operating manoeuvres of a railway.

3.2 Host Computer Module Summary

The present Host consists of the following modules:

- Host Network Manager.
- Command Manager.
- Network Communications Interface.
- Dispatch Communications Interface.
- Debugger/Simulator.

Figure 3-1 shows the relationship between the Host computer modules. The Host has been written in a modular form to allow ease of program debugging, alterations and maintenance. This allows inter-dependencies to be easily handled, for example, Tracking and Control. This also allows the system to be distributed into different sections by migrating each module to a separate computer. For a detailed description of individual module functions refer to Appendix D.

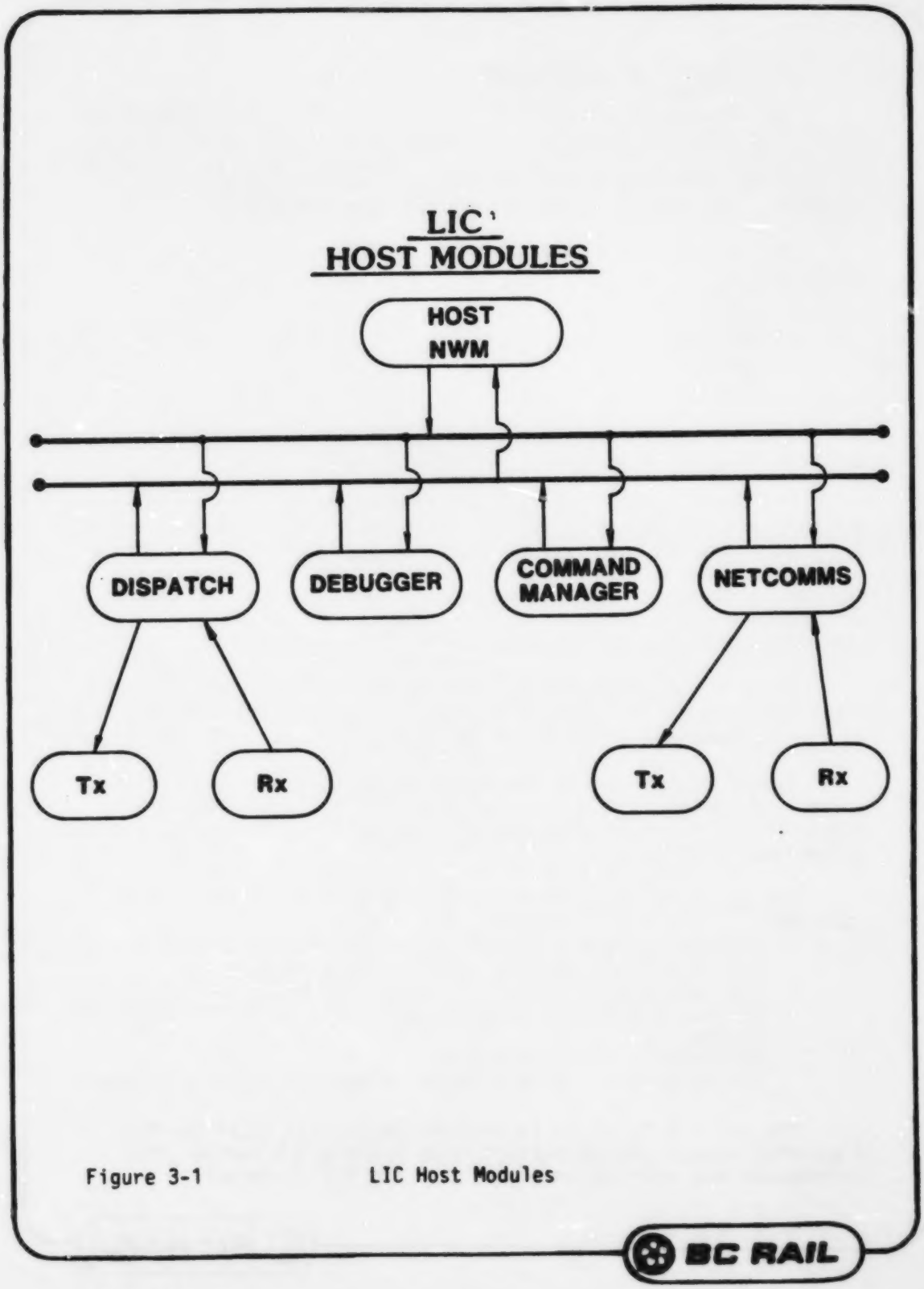


Figure 3-1 LIC Host Modules

3.3 Dispatcher's Interface

The dispatcher's interface is a DEC PRO 350. The video screen is divided into two sections. The upper part of the screen is used for displaying the track model blocks. The lower part of the screen is used for accepting dispatcher commands and displaying error messages. See Figure 3-2 for an example of a CRT layout.

The dispatcher can issue any of the following five major commands:

- Create
- Issue
- Revise
- Cancel
- Comms

Each of these commands are written in separate modules to allow for ease of program debugging, and maintenance.

The Create command is used when the dispatcher wishes to create a train or track occupancy permit. The Issue command is used to issue the train movement authority or track occupancy permit. The Revise command is used to change either a created train or an issued train. The Cancel command is used to cancel a created command, an issued command or a track occupancy permit. The Comms command is used for communications, but at this time has not been implemented.

Each of the commands will require the dispatcher to enter the pertinent information. The data that is collected from the dispatcher is then transferred to the Host computer.

System error messages are displayed on the lower part of the screen. These error messages come from the Host and inform the dispatcher of any command errors in the database. The dispatcher must acknowledge this error.

The following information is displayed on the dispatcher's terminal:

- a scale representation of the subdivision main track showing all sidings and selected additional trackage.
- the location, identity, and depending on the type of authority held, the direction of travel of all LIC equipped trains.
- authorities issued to trains.
- the identities and work limits of maintenance of way crews.

The above information is updated constantly, therefore the dispatcher always has the current track information screen. The information for updating is passed from the Host computer.

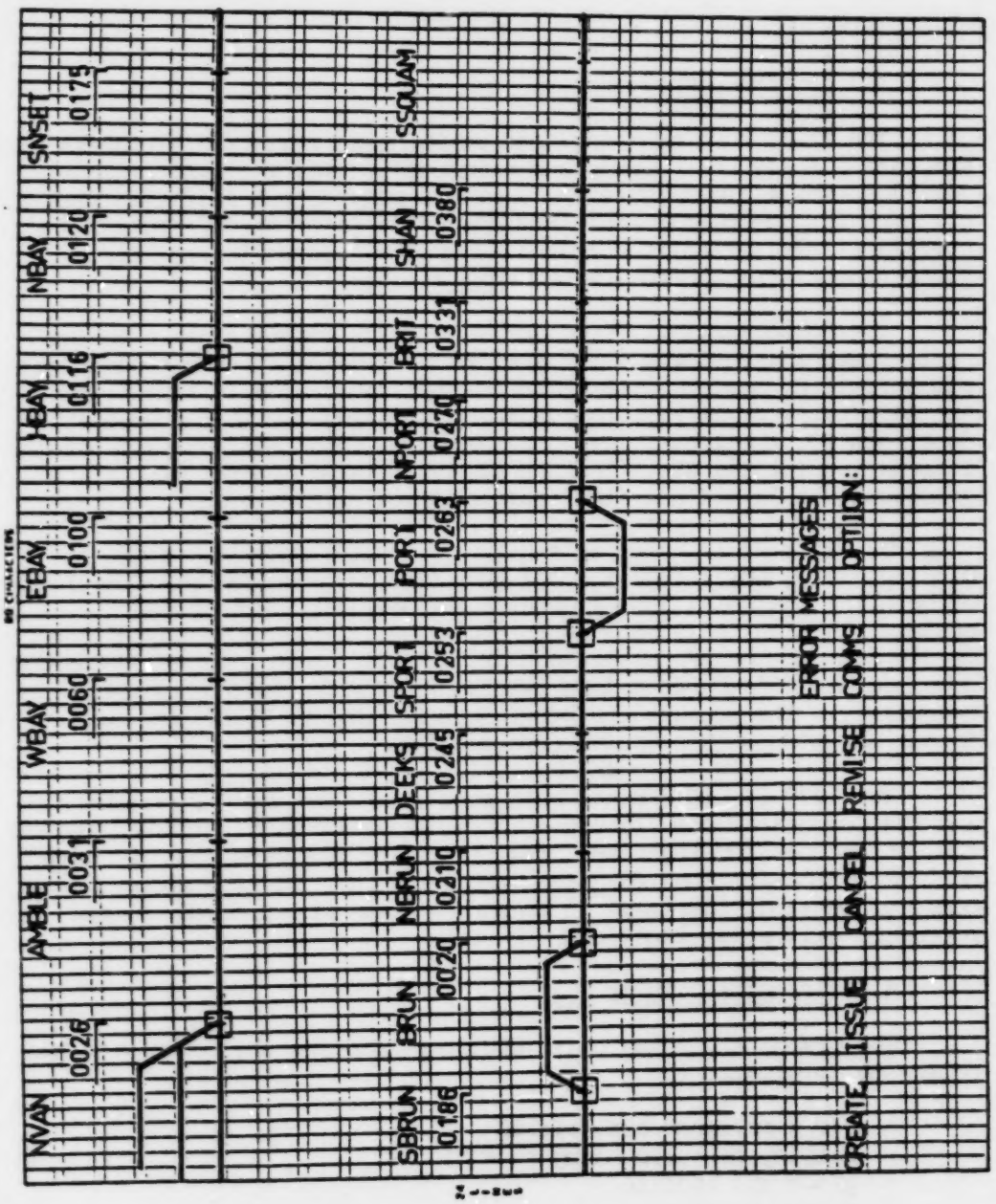


Figure 3-2 Dispatcher's Interface Screen

4. LOCOMOTIVE EQUIPMENT DEVELOPMENT

4.1 System Comparison

The train equipment includes an On Board Train (OBT) processor, Graphics Display Unit (GDU), and a Communications Processor in the lead locomotive (see Figure 4-1). These provide the engineman with a graphics display of all important operating information. This operating information is continually updated and monitored, through processing at the locomotive and central site.

The Communications Processor sends/receives messages from the radio tower and performs the front end processing for the locomotive communications system. The Communications processor is linked with the OBT. The OBT is responsible for performing the main processing functions for the locomotive. The major task for the OBT is providing information for the GDU. The GDU provides the engineman with a graphical display of all important operating information.

The 1979-84 LIC used an Engine Logic Unit (ELU) and a Cab Display Unit (CDU) in the locomotive. The ELU provided the functions of both the Communications Processor and the OBT in the present system. The limited expansion capabilities of the ELU prompted the development of the two separate units for the present system. The CDU provided a 6 line by 40 column display with very limited expansion capability. The present GDU provides a 24 line by 80 column display format and possesses graphics capabilities.

The 1979-84 LIC ELU has been separated into the OBT processor and the Communications Processor to divide the communications function from the processing function. The Communications Processor performs only the communications functions and leaves the OBT processor to do other processing, therefore if communications should cease the OBT processor will still function.

4.2 Graphics Display Unit

The Graphics Display Unit (GDU) provides the engineman with the following information:

- block movement authorities
- display of surrounding five blocks
- grade and profile
- actual speed
- authorized speed
- authorized next speed

- odometer giving track mileage to the nearest 0.1 mile
- system messages

A mock up of this unit has been made on a microcomputer for demonstration purposes.

BC RAIL

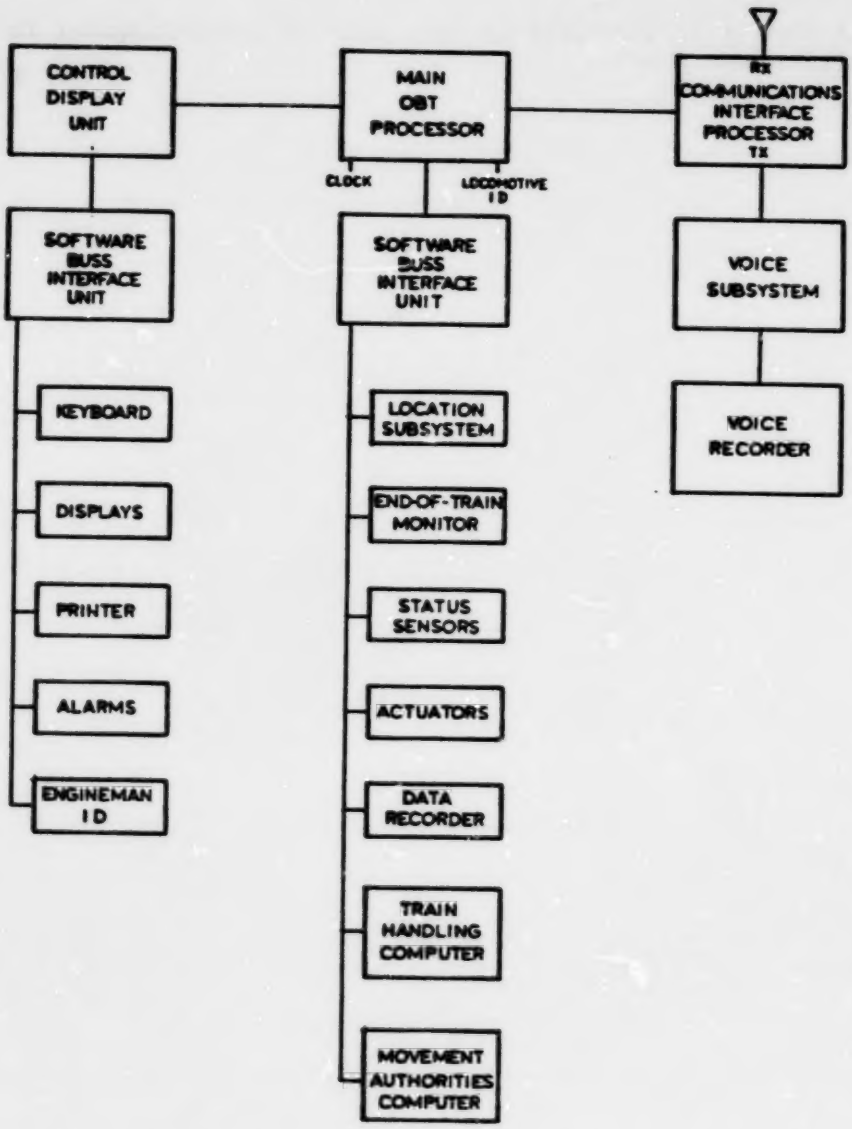


Figure 4-1 Locomotive Components

BC RAIL

4.3 Communications Processor

The Communications Processor handles the communications function for the train. For detailed functions refer to Section 2.5.

4.4 OBT Processor

The OBT processor provides the following functions:

- identifies locomotive
- identifies end of train
- identifies engineman
- receives authorities
- provides data for GDU
- performs diagnostics

4.5 Equipment Installation

The locomotive equipment was not installed in the track inspection vehicle (V-10) due to the fact that the Host computer was not functioning correctly. For this reason it was felt that installation of this equipment was not required at this time. The time frame to install this equipment is minimal, therefore it can be installed as soon as the Host computer is working.

5. TUMBLER RIDGE SUBDIVISION INSTALLATION AND TESTING

5.1 Installation

There were 15 transponders installed between Tacheeda and Wakely in electrified railway territory (see Figure 5-1). Figure 5-2 and Figure 5-3 show the transponder deployment for the Squamish subdivision. Refer to Appendix C for exact transponder locations and numbers. The transponders were installed with the identical configuration as that from the Squamish subdivision between Miles 38 and 42. This would allow similar testing to be performed in both subdivisions. Also this permits the use of the same hardware and software, with minor transponder number file alterations, as that used at the Squamish subdivision.

The RPU was not installed in the Tumbler Ridge Subdivision; it was to be moved from the Squamish Subdivision after the completion of testing. Testing was not performed because of the problem with the Host computer.

The dedicated voice grade microwave channel was provided from the Tumber Ridge subdivision to the North Vancouver dispatching centre.

5.2 Testing

The Host computer and Host computer software were not performing adequately and, therefore, testing could not commence as scheduled. Weather conditions later contributed to complications in which testing could not proceed.

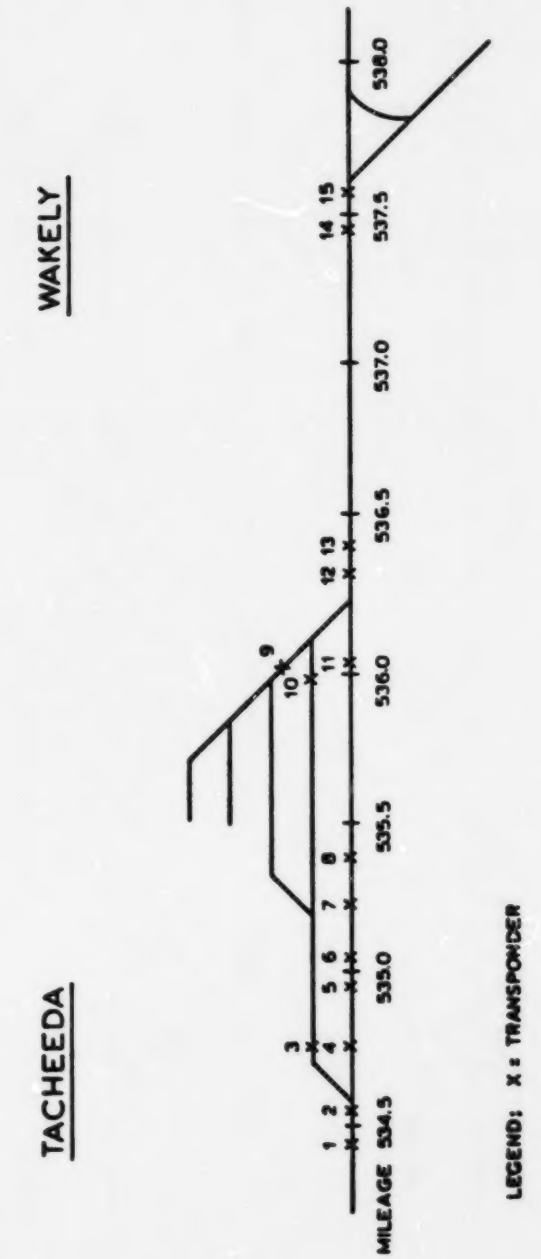


Figure 5-1 Transponder Deployment in Electrified Territory

BC RAIL

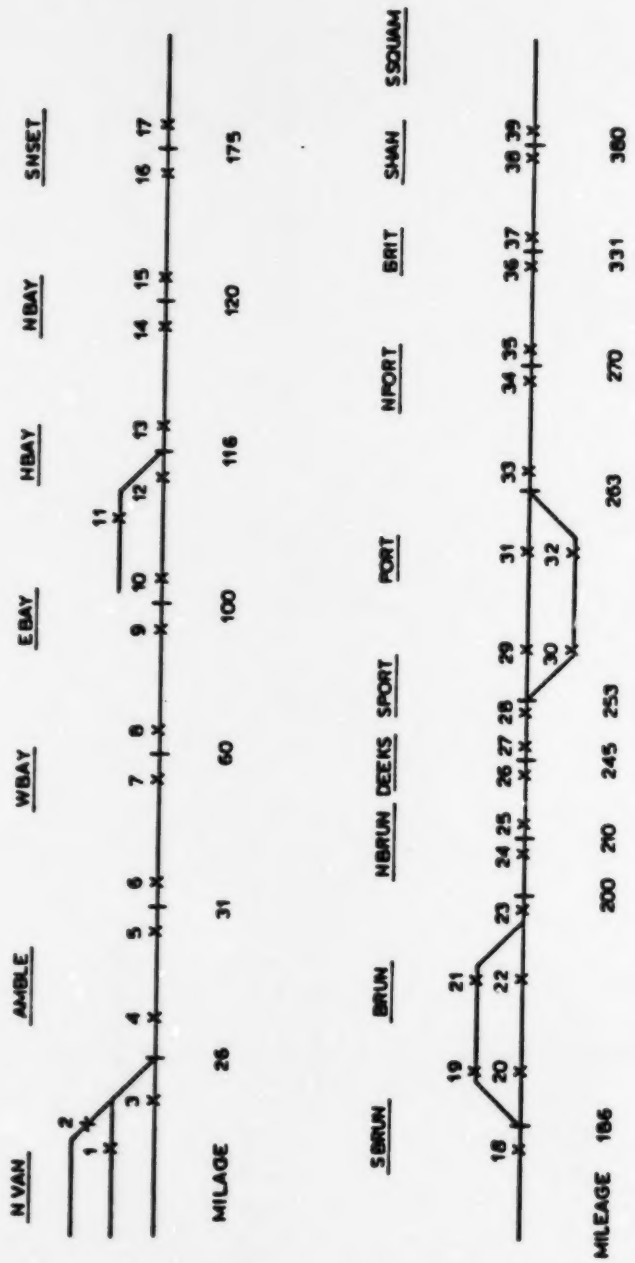


Figure 5-2 Transponder Deployment for the Squamish Subdivision

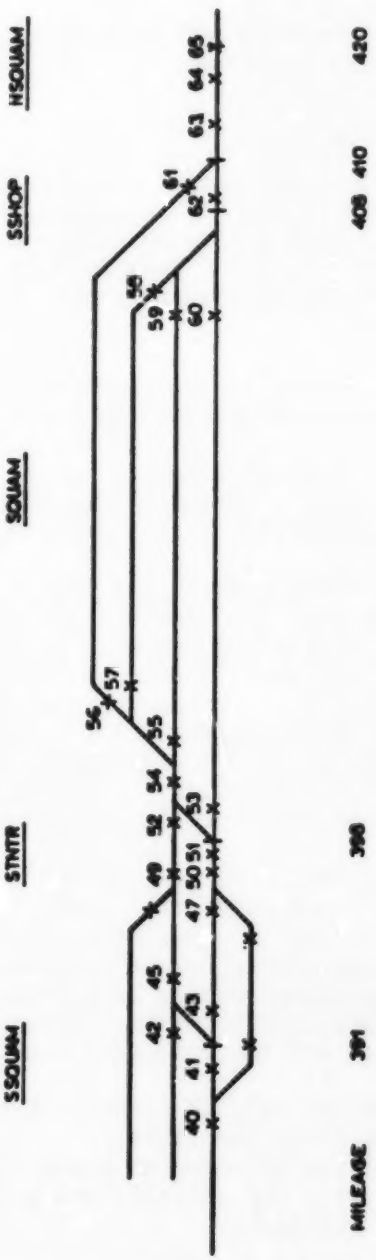


Figure 5-3 Transponder Deployment for the Squamish Subdivision

6. DEVELOPMENT PROBLEMS ENCOUNTERED

The development problems encountered during this project centered around the Host computer.

6.1 Host Computer

The major problem encountered with the Host development was inter-process communication and synchronization. The passing or sharing of data between the different processes became the central issue in the design of the Host. This problem cannot be attributed to solely the computer or the operating system, but rather the combination of the two.

The operation system that was chosen was Ultrix-11 Version 2.0. This operating system was chosen for the following reasons:

- excellent software development tools.
- the 'C' programming language came with the operating system.
- 'C' is well supported by the operating system.

In our opinion, other operating systems fell far short from having the development tools and the support of Ultrix. Although 'C' is available for other operating systems, it usually is not supplied with the operating system and therefore support is not as good as with Ultrix. The other consideration was the fact that a good 'C' compiler for other operating systems costs about the same as Ultrix, which comes with a 'C' compiler. The 'C' language is a major selection criterion because of its portability. Despite its lack of official standards, 'C' is one of the most standarized languages.

The Ultrix-11 operating system did not allow the use of common storage techniques to store data; this would have been the simplest and most efficient solution to inter-process communications. The only way that was found to pass data between two processes was a 'pipe'. A pipe is a specially allocated memory area that, at a programming level, operates the same as a sequential file. These pipes could not be used for common data for the following two reasons:

- the pipe size was only 4K bytes, but the system data base required more space than this.
- the pipes operate the same as a sequential file, therefore data must be read sequentially and once it has been read, it is no longer available.

For these reasons, pipes could only be used to pass temporary data between the modules and one module had to be appointed as a database manager.

Although pipes did allow the passing of data between processes (tasks), they could not be used freely in the design of the Host. All input and output, such as files, asynchronous ports, and pipes, require a logical data type known as a file descriptor (fd). Ultrix-11 allowed only 21 file descriptors, which presented another development problem. Although the Host design was able to be implemented, there was absolutely no room for even the smallest expansion of the system. That meant that features, such as Communication Error Reporting and Significant Events Recording, could not be implemented. The file descriptors were allocated in the following manner:

- three were automatically allocated, by the operating system, to the CRT and the keyboard.
- four were required for asynchronous communications to the dispatcher's computer and the network controller.
- twelve were required for the 6 pipes that were used for diagnostics and debugging.

Once a means of passing data between modules had been determined, the next development problem was process synchronization. The processes had to know when they were being passed data via a pipe. There was only one way of attaining this with the Ultrix operating system and that was to implement 'signals'. Signals are a program level implementation of hardware interrupts or traps. The problem encountered with this method of process synchronization was reliability. The heavier the use of the system the more unreliable the signals became. The unreliability of these signals was a major problem, in that if the program was not expecting the signal, the signal would cause the program to crash.

The problem with hardware was the size and speed. The PDP has a 16-bit microprocessor and 512 kilobytes of physical memory. This lack of power contributed to the Host software and Ultrix's inability to handle multiple signals or interrupts. The Ultrix operating system used approximately 356K, leaving only 156K for the Host software. The Host software was approximately 226K; this meant the modules of the Host were constantly being swapped in and out of memory. This lead to the following two problems:

- the time required to perform the swapping greatly reduced the power and speed of the Host.
- it created the possibility that a module, that was supposed to catch a signal, had been swapped out of memory when the signal was generated.

The PRO 350 was slow to use during the development stages for the Dispatcher's Interface. System portability and flexibility is a concern because the Dispatcher's Interface is written in Fortran.

7. CONCLUSIONS

This section contains the conclusions which can be made for the present LIC system development based on the experience gained and the information presented in this report:

7.1 Communications

The following conclusions can be made about the communications system:

- the communications were redeveloped, which included the Network Manager, Cluster Controller, Site Processor, RPU and Modem.
- the message format was changed.
- modem speed was increased to 1200 b.p.s.
- communications were switched from asynchronous to synchronous.

7.2 Host Computer

The following conclusions can be made about the Host computer:

- the hardware is unable to efficiently run the software due to execution speed, and internal and external memory size.
- the PDP 11/44 16 bit processor does not perform the required processing in an efficient time frame due to the fact that 15 year old technology is being implemented.
- the Ultrix-11 operating system lacks the common storage capability that is required to allow efficient implementation of the Host software.
- the 'C' language that was chosen for system development has proven to be effective in implementing the software.

7.3 Locomotive Equipment

The following conclusions can be made about the locomotive equipment:

- the locomotive equipment was redeveloped, which included the OBT processor, communications processor, and the GDU.
- the GDT was a mock up provided on a microcomputer.
- equipment was not installed on the track inspection car (V-10) due to the problem with the Host computer.

7.4 Tumbler Ridge Subdivision

The following conclusions can be made about the Tumbler Ridge subdivision:

- transponders and modems were installed.
- the RPU was not moved from the Squamish subdivision.
- the microwave channel was provided between Tumbler Ridge and the North Vancouver dispatching centre.
- tests were not run because of problems with the Host computer, therefore there were no test results available for comparisons to be made.

8. RECOMMENDATIONS

On the basis of the information presented in the preceding Sections and the conclusions drawn from it, the following recommendations are made:

- purchase new Host computer (Micro Vax II).
- port software to new Host computer.
- evaluate possibility of transporting the Dispatcher's Interface from the PRO 350 to the new Host to achieve better compatibility and portability.
- extensively test communications system in mobile environment and prove system meets EEA standard for mobile data communications.
- display and handle non-equipped trains.
- display OBT graphics on a practical display unit.
- perform indepth traffic analysis of BCN and mobile communications network.
- enhance communications software to include analysis of communications statistics and real-time graphing of results.
- enhance OBT tracking to include all possible failure modes and compensations to dead reckoning.
- demonstrate end-of-train unit interface.
- demonstrate inclusion of wayside processors.
- demonstrate system with tracking and control.

APPENDIX A Protocols

The following three protocols are used in the present LIC systems:

- Host computer to/from Network Manager (see Figure A-1).
- Host computer to/from Dispatcher's Interface (see Figure A-2).
- Network Manager to/from Backbone Communications Network, which is the EEA standard (see Figure A-3).

Referring to Figures A-1, A-2, and A-3 the length, in bits, of each item is designated by the number in brackets. These communications protocols are designed to ensure a high probability of error detection. The protocols are made up of the following items:

1. SOM - signifies Start of Message.

2. Sync - characters used for synchronizing communications.

3. Cont - control bits (Normal, User Ack, NAK, and ACK).

4. Proc - process of message (e.g. EEA, ISSUE, and REVISE).

5. Destination - destination of the message.

6. Source - source of message.

7. Process Arg - process argument that contains that which is particular to each process.

8. CRC - Cyclic Redundancy Check for parity.

9. Data - message data.

10. EOM - signifies End of Message.

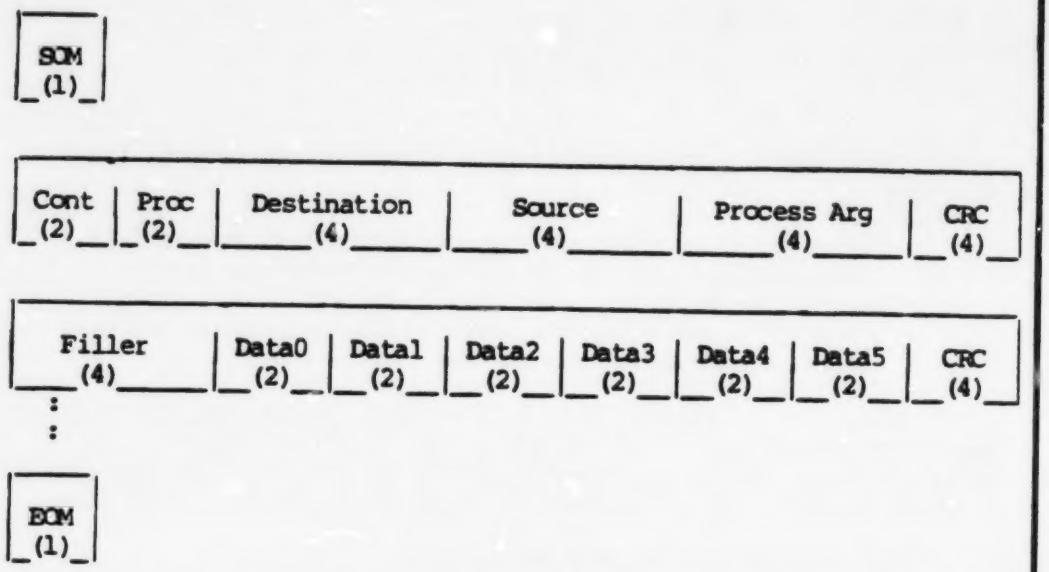


Figure A-1 Host Computer to Network Manager

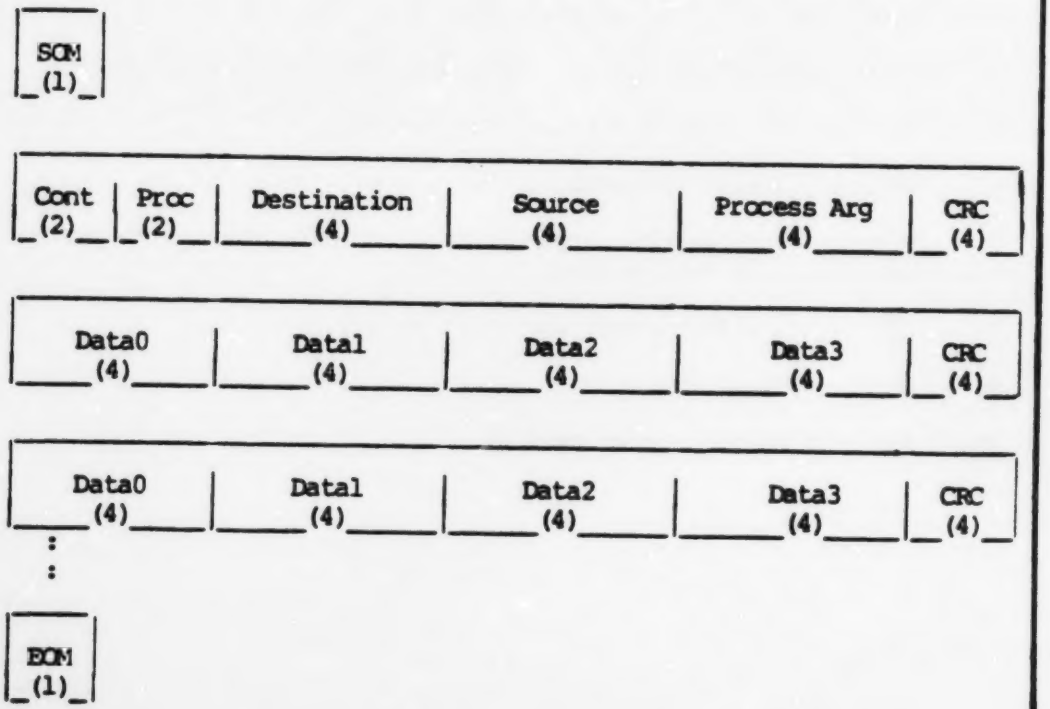


Figure A-2 Host Computer to Dispatcher's Interface

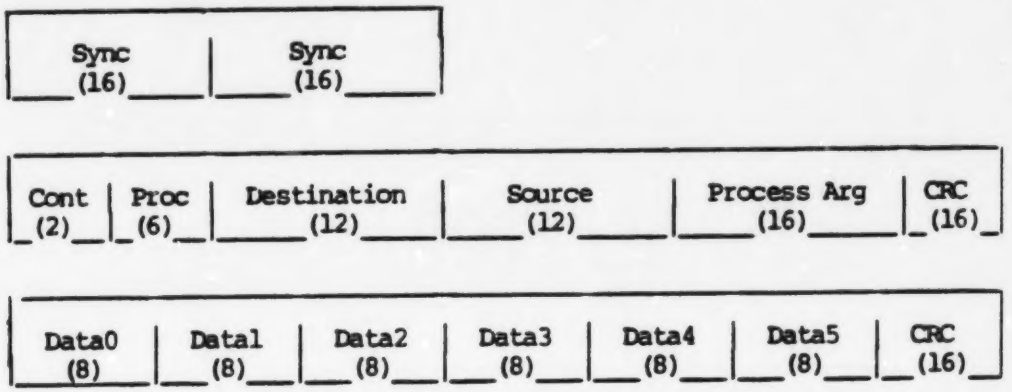


Figure A-3 Network Manager to Backbone Communications Network

APPENDIX B System Drawings

The following three system drawings are presented in this section:

- LIC System Overview (Figure B-1)
- LIC Message Flow (Figure B-2)
- LIC Cluster Controller Block Diagram (Figure B-3)

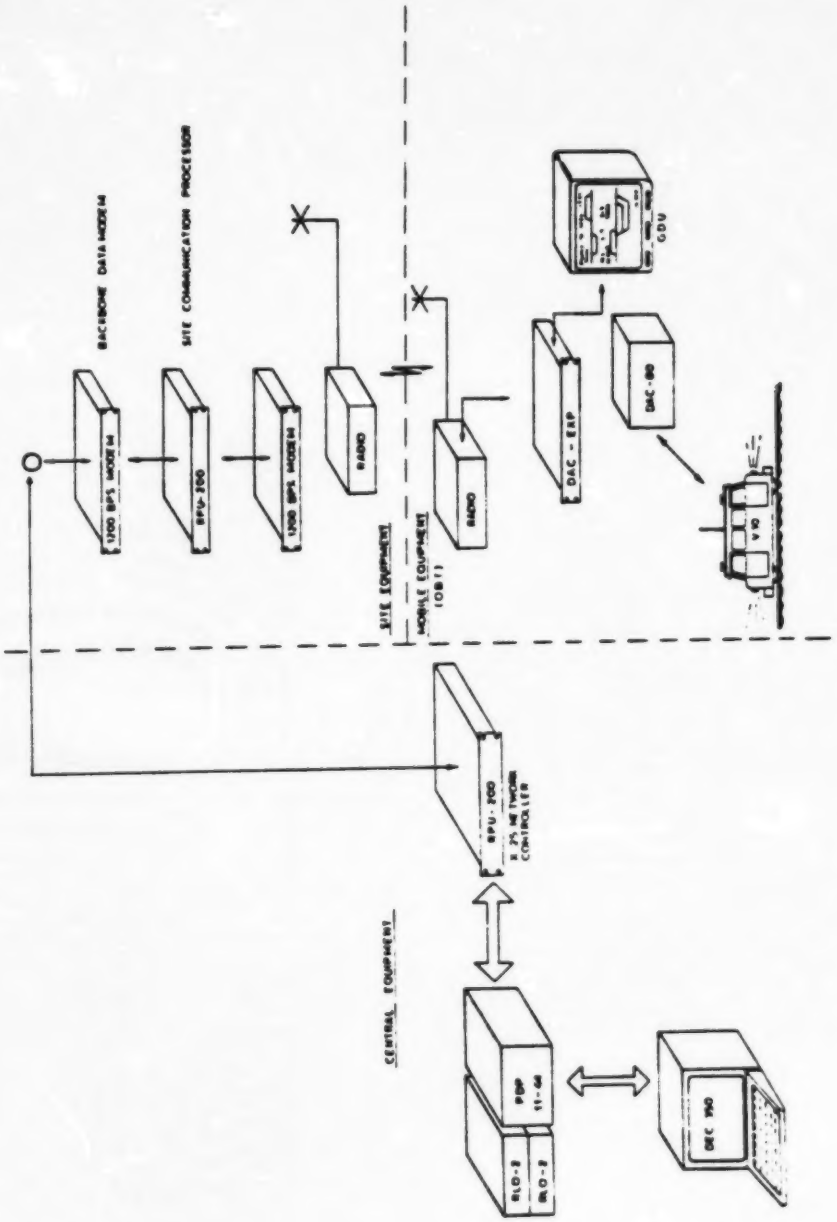


Figure B-1 LIC System Overview

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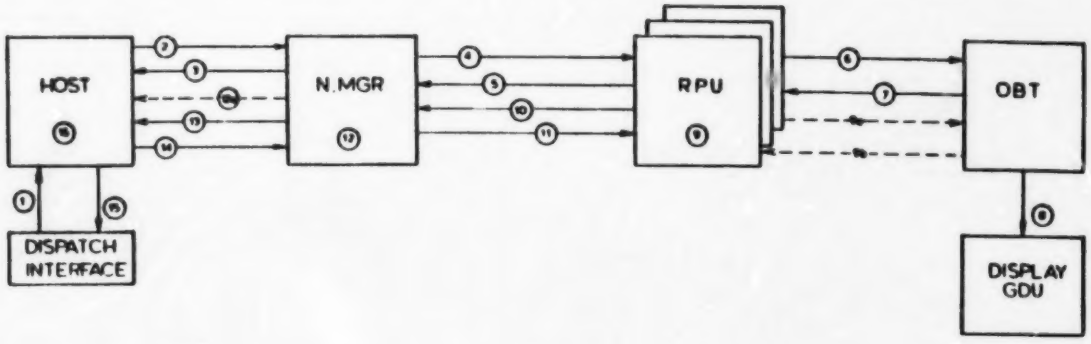

Figure B-2 LIC Message Flow

1. ISSUE COMMAND FOR A TRAIN TO OCCUPY BLOCKS OF TRACK
2. BROADCAST OK FOR TRAIN TO:
3. ACKNOWLEGED RECEIVED MESSAGE
4. RPUs BROADCAST MESSAGE
5. ACKNOWLEDGED WILL DO
6. MESSAGE BROADCAST
7. RECEIVED MESSAGE
8. DISPLAY
9. ? ALL OBTs RECEIVED MESSAGE. NO GO TO 9A
   - 9A) BROADCAST MESSAGE REPEAT
   - 9B) ACKNOWLEDGE RECEIVED MESSAGE
10. SITE BROADCAST COMPLETE WITH OR WITH OUT MESSAGE
11. MESSAGE RECEIVED N. MANAGER
12. ? ALL RPUs HAVE REPORTED COMPLETE. NO GO TO 12A (TIMEOUT)
    - 12A) ERROR BCN RPU DOWN?
13. MESSAGE COMPLETE WITH OR WITHOUT ERRORS
14. MESSAGE RECEIVED
15. GRAPHICS STOPS FLASHING
16. END OR UPDATE COMMUNICATORS FAIL LIST

BC RAIL

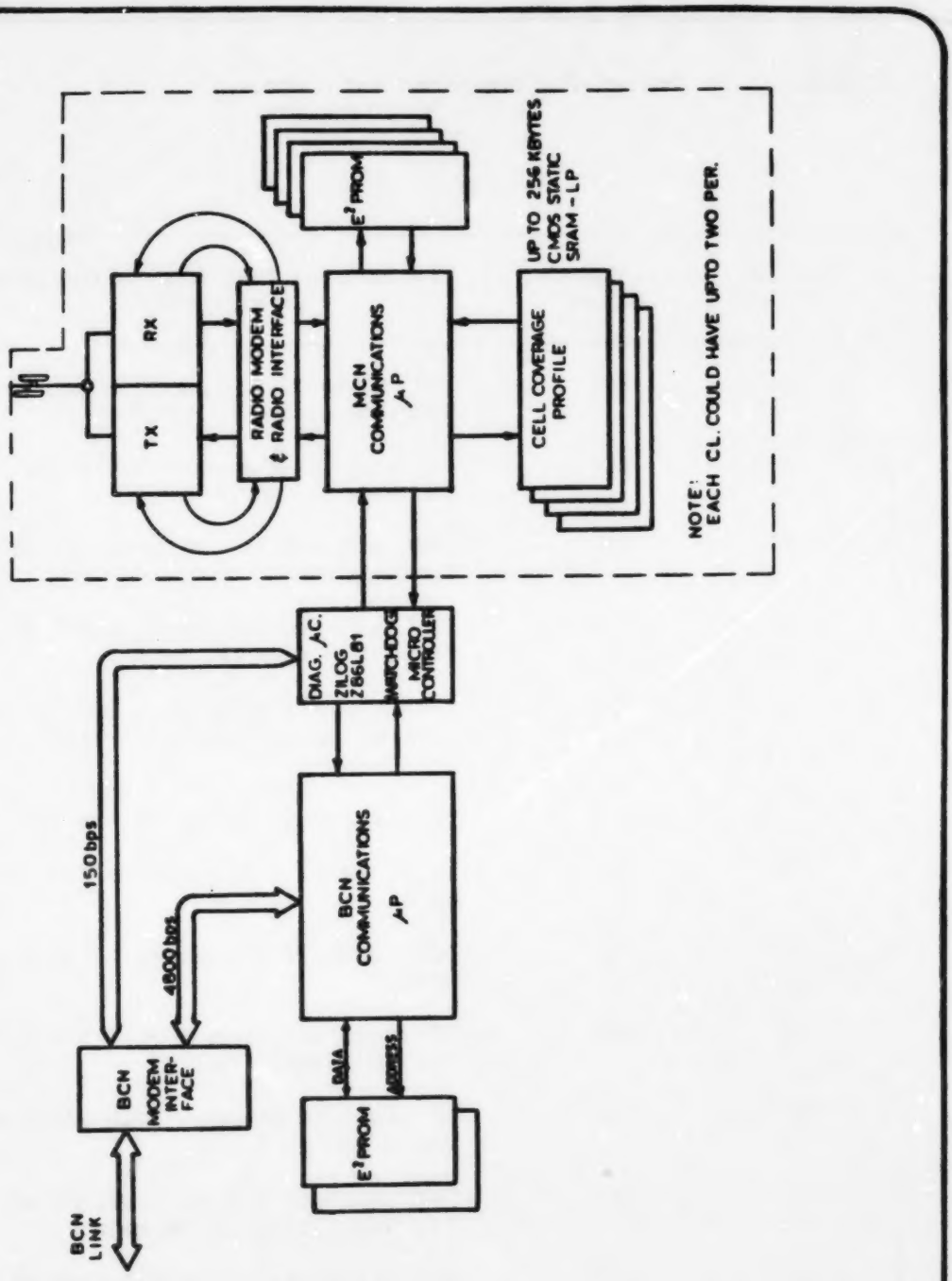

Figure B-3 LIC Cluster Controller Block Diagram

APPENDIX C Transponder Locations and Numbers

Location	Transponder Number	Placement as Feet from Switch Point or Mileage
1	247	250' south of the south switch of Tacheeda Siding on the Main
2	217	46' south of the south switch of Tacheeda Siding on the Main
3	136	180' north of the south switch of Tacheeda Siding on the Siding
4	253	180' north of the south switch of Tacheeda Siding on the Main
5	123	180' south of Mile 535.4 additional trackage south switch on the Main
6	271	80' north of Mile 535.4 additional trackage south switch on the Main
7	214	1035' north of Transponder 6 on the Main
8	059	260' north of Transponder 7 on the Main
9	048	50' south of catenary Pole 536.1 on the additional trackage
10	054	30' north of catenary Pole 536.1 on the siding
11	222	180' south of the north switch of Tacheeda Siding on the Main
12	236	100' north of the north switch of Tacheeda Siding on the Main

Table C-1 Transponder Deployment in Electrified Territory

Location	Transponder Number	Placement as Feet from Switch Point or Mileage
13	267	550' north of the north switch of Tacheeda Siding on the Main
14	207	2230' north of Mile 537 on the Main
15	060	50' north of Transponder 14

Table C-1 Transponder Deployment in Electrified Territory

Location	Transponder Number	Placement as Feet from Switch Point or Mileage
1	247	140' south of Wharf track switch on lead
2	123	140' south of Wharf track switch on lead
3	233	180' south of North Pass switch on old main track
4	042	80' north of North Pass switch
5	136	25' south of Mileage 3.1
6	224	25' north of Mileage 3.1
7	220	26' south of Mileage 6.0
8	247	25' north of Mileage 6.0
9	234	10' south of Mileage 10.0
10	242	40' north of Mileage 10.0
11	138	175' south of switch in siding
12	210	175' south of switch on main track
13	153	80' north of switch on main track
14	271	25' south of Mileage 12.0
15	050	25' north of Mileage 12.0
16	155	25' south of Mileage 17.5
17	278	25' north of Mileage 17.5
18	236	100' south of south switch Brunswick

Table C-2 Transponder Deployment in the Squamish Subdivision

Location	Transponder Number	Placement as Feet from Switch Point or Mileage
19	239	175' north of south switch Brunswick in siding
20	267	175' north of south switch Brunswick in siding
21	231	170' south of north switch Brunswick on main track
22	214	170' south of north switch Brunswick on main track
23	265	80' north of north switch Brunswick
24	172	25' south of Mileage 21.0
25	054	25' north of Mileage 21.0
26	135	25' south of Mileage 24.5
27	145	25' north of Mileage 24.5
28	055	80' south of south switch Porteau
29	057	170' north of south switch Porteau in siding
30	056	170' north of south switch Porteau on main track
31	059	174' south of north switch Porteau in siding
32	293	174' south of north switch Porteau in siding
33	060	80' north of north switch Porteau
34	079	25' south of Mileage 27.0

Table C-2 Transponder Deployment in the Squamish Subdivision

Location	Transponder Number	Placement as Feet from Switch Point or Mileage
35	297	25' north of Mileage 27.0
36	207	25' south of Mileage 33.1
37	205	25' north of Mileage 33.1
38	253	25' south of Mileage 38.0
39	268	25' north of Mileage 38.0
40	181	80' south of south switch to station track
41	062	170' north of south switch to station track, 46' south of south switch to siding
42	215	180' north of south switch siding on main track
43	284	170' north of south switch station track on station track
44	226	190' south of north switch station track on station track
45	294	80' north of north station track switch on main track
46	244	190' south of north station track switch on main track
47	131	180' south of wharf track switch on wharf track
48	126	80' north of wharf track switch on siding
49	061	80' north of south crossover switch to siding

Table C-2 Transponder Deployment in the Squamish Subdivision

Location	Transponder Number	Placement as Feet from Switch Point or Mileage
50	133	180' south of south crossover switch to siding
51	051	80' south of Buckley's crossover switch on siding
52	072	180' north of Buckley's crossover switch on siding
53	140	180' south of Buckley's crossover switch on siding
54	173	80' south of south lead switch on siding
55	018	180' north of south lead switch on siding
56	073	138' north of No. 1 track switch on lead
57	260	180' north of No. 1 track switch on No. 1 track
58	119	150' south of north lead track switch on the lead
59	230	180' south of north lead track switch on siding
60	238	180' south of north passing track switch on siding
61	275	100' north of north switch siding on main track
62	243	80' north of north switch to shop lead on main track

Table C-2 Transponder Deployment in the Squamish Subdivision

Location	Transponder Number	Placement as Feet from Switch Point or Mileage
63	261	157' south of north shop lead switch on shop lead
64	213	25' south of Mileage 42.0
65	277	25' north of Mileage 42.0

Table C-2 Transponder Deployment in the Squamish Subdivision

APPENDIX D Host Module Description

1. Host Network Manager

The modules are arranged in a hierarchical structure, with the Host Network Manager module serving as the network controller. This network, called the Host Network, is based upon a bid and grant system. In order for Module 'A' to pass data to Module 'B', the following events must take place:

1. Module 'A' checks to see if the Host Network is busy.

2. If the Host Network is free, Module 'A' will request use of the network.

3. The Host Network Manager grants use of the system to Module 'A' and tells all other modules that the network is now busy.

4. Module 'A' writes the data, in a packet format (see Appendix A), into a specially allocated memory area. This memory location (Memory Area 1) is known to all the other modules and is used only for writing to. There is another specially allocated memory area (Memory Area 2) that is used only for reading. The only module that does not use these two memory areas in this fashion is the Host Network Manager. The Host Network Manager reads from Memory Area 1 and writes to Memory Area 2, which is the opposite of all other modules.

5. The Host Network Manager reads the data from Memory Area 1.

6. The destination of the packet is determined from the destination field in the data packet (see Appendix A).

7. The Host Network Manager writes the packet into Memory Area 2, tells Module 'B' that there is data for it to read, and waits for Module 'B' to write its response into Memory Area 1.

8. Module 'B' reads the data from memory Area 2 and if no errors are detected in the packet, writes it into Memory Area 1.

9. The Host Network Manager reads the data in from Memory Area 1, writes the data into Memory Area 2, and tells Module 'A' that there is data for it to read.

10. Module 'A' reads the data from Memory Area 2, checks the data against the original that was sent, and if no errors, continues processing.

11. The Host Network Manager tells all modules that the network is now free and waits for the next request.

2. Command Manager

This module is responsible for the processing of commands sent by the dispatcher and the communications network. The commands include:

- CREATE - create a train or track occupancy permit.
- ISSUE - issue a train or track occupancy permit.
- CANCEL - cancel a train or track occupancy permit.
- REVISE - revise an issue.
- RVSCREAT - revise a create.
- O.S. - status change of a train.

The Command Manager is responsible for detecting and reporting conflicts or errors in any of the commands. The Command Manager also maintains the system database. The system database contains the data needed for modeling train movements and authorities in a fixed block environment. The following steps are executed by the Command Manager upon receipt of a new command:

1. The Command Manager is notified by the Host Network Manager that there is data for it to read.

2. The Command Manager stops its current processing and reads the data from the common read location in memory.

3. Provided no errors are detected in the packet, the Command Manager writes the data into the 'write memory area'.

4. The data is then stripped of its packet overhead and placed at the end of a First-In-First-Out (FIFO) command queue.

5. The Command Manager then returns to the processing it had been doing.

As long as there are commands in the queue, the Command Manager continues to run. If the command queue ever empties, the Command Manager sets an alarm for a number of seconds and sleeps until the alarm wakes it up. This continues until a command is placed in the command queue.

3. Network and Dispatcher Communications Interface

These two modules do essentially the same things, they are both communications programs. They receive data in one protocol, convert the data into another protocol, and send it to its destination. The programs send one message at a time and must wait for an acknowledgement (ACK) before it can send the next message. After a number of unsuccessful attempts at sending the message, the programs report the communications failure and go onto the next message. These reported communication failures are passed on to the dispatcher. The dispatcher then chooses, at a convenient time to him, how to handle the communications error.

These programs must buffer messages because many packets may come in while it is waiting for an ACK of a previously sent packet. The programs must handle one protocol for packets within the Host Network and another for packets in the Communications Network. See Appendix A for a more detailed description of the protocols.

4. Debugger/Simulator

This module was developed to aid in debugging and exercising the Host. Because the Host is designed with a network structure, the packets of data that pass between the modules are not module dependent. That is, a packet that has a 'Create' command in it can have any source point. The command can come from the simulator module as easily as it could come from the Dispatcher Communications Interface. This flexibility allows one or more modules to be tested, or exercised, without the entire system being able to run. This approach reduces the number of variables in the system, thereby making the location of software errors much simpler.

GLOSSARY

Baud

The signalling rate, in a number of times per second, that the signal changes in a communications circuit.

Block

A uniquely defined and identified length of track in LIC territory; may be one of the following types: main track, siding, or additional trackage.

Cab Display Unit (CDU)

An alphanumeric display in the locomotive cab, used in 1979-84 LIC, which indicates train speed, location (mileage), and movement authority information.

Dispatcher's Interface

A microcomputer in the central subsystem used to gather train operations data from the dispatcher.

Engine Logic Unit (ELU)

A zilog Z-80 based microprocessor, used in 1979-84 LIC, which is the heart of the engine and caboose mounted electronic equipment.

Host

The primary computer in the central control subsystem used for all data processing and control execution functions.

Modem

Short for modulator-demodulator - a device which converts a serial bit stream into a form which can be transmitted by radio or telephone.

Operating Authorities

A train control command issued by the train dispatcher either by cab display or in written form, authorizing train movement within LIC territory.

Transponder

A passive electronic device fastened to the road bed in a location precisely known by the LIC central computer; when energized by a passing LIC vehicle, it transmits a unique identifier.

BC RAIL

ABBREVIATIONS

ACK

Acknowledgement

BCN

Backbone Communications Network

CDU

Cab Display Unit

CRC

Cyclic Redundancy Check

CRT

Cathode Ray Tube

DCP

Data Collection Processor

EEA

European Engineering Association

ELU

Engine Logic Unit

FFSK
Fast Frequency Shift Keying

FIFO

First in First Out

GDU

Graphics Display Unit

ISO OSI

International Standards Organization Open System Interface

LIC

Location, Identification and Control

MSK

Minimum Shift Keying

NWM

Network Manager

OBT

On Board Train Processor

RDC

Rail Diesel Car

RPU

Remote Processing Unit

WCN

Wayside Communications Network

WSP

Wayside Processor